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(71) Applicant:
MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
Kadoma-shi, Osaka 571 (JP)

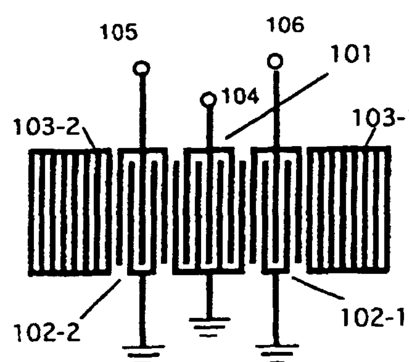
(72) Inventors:
- Taguchi, Yutaka
Takatsuki-shi, Osaka 569 (JP)
- Eda, Kazuo
Nara-shi, Nara 631 (JP)
- Seki, Shun-ichi
Amagasaki-shi, Hyogo 661 (JP)
- Onishi, Keiji
Settsu-shi, Osaka 566 (JP)
- Murase, Yasumichi
Nishinomiya-shi, Hyogo 663 (JP)
- Nishimura, Kazunori
Yawata-shi, Kyoto 614 (JP)
- Mita, Narihiro
Izumisano-shi, Osaka 598 (JP)

(74) Representative: Eisenführ, Speiser & Partner
Martinistrasse 24
28195 Bremen (DE)

(54) Surface acoustic wave filter

(57) The surface acoustic wave filter is provided with a distribution function and preferably a balance-unbalanced conversion function. Typically, in the three electrode vertical mode surface acoustic wave filter, a space between said second comb-like electrodes 305-1 provided with an outputting terminal of said first side interdigital transducer and said first comb-like electrodes 304-1 provided with an inputting terminal of said central interdigital transducer is different at one or odd number times of half wavelength (λ/2) from a space between said second comb-like electrodes 305-2 provided with an outputting terminal of said second side interdigital transducer and said first comb-like electrodes 304-1 provided with an inputting terminal of said central interdigital transducer, whereby one unbalanced input signal entering into said central interdigital transducer 304 is distributed through said side interdigital transducers into at least two output signals having balanced relation to each other with respect to phase.

Fig. 1



EP 0 800 270 A2

Description

FIELD OF THE INVENTION

The present invention relates to a surface acoustic wave (SAW) filter provided with a distributor function, and more particularly to a surface acoustic wave filter for use in a high frequency region such as RF-band.

BACKGROUND OF THE INVENTION

In recent years, research has been carried out briskly on a surface acoustic wave element for use in a filter. In particular, a recent advancement of mobile communication and a higher frequency has led to a brisk development of a surface acoustic wave element, particularly a surface acoustic wave filter.

Conventionally, there are known several kinds of methods for constituting a filter of a surface acoustic wave element in a high frequency region, particularly in several hundred MHz such as RF-band (950 MHz). Typical methods of such kinds include a method of ladder type for constituting a filter by using a plurality of surface acoustic resonators as disclosed in Japanese Unexamined Patent Publication No. 52-19044, a method of so-called multiple electrode type as disclosed in Japanese Unexamined Patent Publication No. 58-154917, a method of vertical mode type as disclosed in Japanese Unexamined Patent Publication No. 3-2225112, Japanese Unexamined Patent Publication No. 61-230419 and Japanese Unexamined Patent Publication No. 1-231417 wherein surface acoustic wave resonators are located adjacent to each other to use a coupling between resonators.

These SAW filters all were dealing with an unbalanced type signal, and their characteristic impedance were set to 50 ohms because of a demand from a user side of the SAW filters. Further, these SAW filters had no distributor function therein, so a separate distributor must be used to distribute one input signal into more than two output signals.

In recent years, there is seen a movement of decreasing the number of parts by allowing parts of a high frequency circuit to incorporate a plurality of functions. Such movement has arisen from a demand on a miniaturization and a cost reduction of such parts. It seems that such a demand will get stronger from now on. As one of such examples, there has been desired a new filter provided with a distributor function. Further, there has been desired a new filter provided with a function for a balanced circuit in order to get a higher performance of the high frequency circuit. In this case, parts for balanced circuit will be required and their characteristic impedance will not be set to 50 ohms similar to that in the conventional unbalanced circuit.

In particular, during a transition period from an unbalanced circuit to a balance circuit, there were required parts such as a balun which has an unbalanced terminal for input and a balanced terminal for output. Although the balun is capable of controlling the impedance of the balanced terminal and the unbalanced terminal depending on the structure thereof, there happ ned a disadvantage in that the cost was increasing and more packag area was required for mounting the balun.

SUMMARY OF THE INVENTION

Therefore, a first object of the present invention is to provide a new surface acoustic wave filter provided with the distributor function. Further, a second object of the present invention is to provide a new balanced-unbalanced type surface acoustic wave filter without using the balun.

Therefore, according to a first aspect of the present invention, there is provided with a surface acoustic wave filter comprising:

> a piezoelectric substrate, surface wave reflectors formed with an interval therebetween on said piezoelectric substrate, and interdigital transducers interposed between said surface wave reflectors on said piezoelectric substrate,
> wherein said interdigital transducers comprises a central interdigital transducer for input, at least two side interdigital transducers, at least one located at one of opposite sides of said central interdigital transducer and the other one located at the other one of opposite sides of said central interdigital transducer,
> said central interdigital transducer for input comprising a pair of first comb-like electrodes provided with an input terminal and second comb-like electrodes provided with a grounding terminal;
> each of said interdigital transducers for output comprising a pair of first comb-like electrodes provided with a connecting terminal and second comb-like electrodes provided with an output terminal, said connecting terminals being connected to each other or grounded together so as to distribute one signal entering into said central interdigital transducer into at least two signals each output from each output terminal of said side interdigital transducers.

In a preferred embodiment of the surface acoustic wave filter according to the present invention, the number of electrodes of said central interdigital transducer for input is substantially equal to that of each said side interdigital transducer for output in order to make an input impedance substantially equal to an output impedance.

Further, according to a second aspect of the present invention, there is provided with a balanced-unbalanced type surface acoustic wave filter, which comprises the abov surface acoustic wave filter, wherein a space between said second comb-like electrodes provided with an outputting terminal of said first

side interdigital transducer and said first comb-like electrodes provided with an inputting terminal of said central interdigital transducer is different at one or odd number times of half wavelength (λ/2) from a spac between said second comb-like electrodes provided with an outputting terminal of said second side interdigital transducer and said first comb-like electrodes provided with an inputting terminal of said central interdigital transducer, whereby one unbalanced input signal entering into said central interdigital transducer is distributed into at least two output signals having balanced relation to each other with respect to phase.

In a preferred embodiment of the balanced-unbalanced type surface acoustic wave filter, wherein the number of electrodes of each said side interdigital transducer for output is smaller than that of said central interdigital transducer for input so as to get an output impedance of said side interdigital transducer larger than an input impedance.

In one embodiment of the balanced-unbalanced type surface acoustic wave filter, the space between an innermost electrode of said first side interdigital transducer and one outermost electrode of said central interdigital transducer may be designed to be different at one or odd number times of half wavelength (λ/2) from the space between an innermost electrode of said second side interdigital transducer and an other outermost electrode of said central interdigital transducer as shown in Figs. 3 and 7.

In another embodiment of the balanced-unbalanced type surface acoustic wave filter, the space between an innermost electrode of said first side interdigital transducer and one outermost electrode of said central interdigital transducer may be designed to be substantially the same as the space between an innermost electrode of said second side interdigital transducer and an other outermost electrode of said central interdigital transducer as shown in Fig. 5.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a structural view showing a surface acoustic wave filter according embodiment 1 of the invention.

Fig. 2 is a structural view showing the surface acoustic wave filter according to embodiment 2 of the invention.

Fig. 3 is a structural view showing the surface acoustic wave filter according to embodiment 3 of the invention.

Fig. 4 is a measurement circuit diagram of the surface acoustic wave filter of the invention.

Fig. 5 is a structural view showing the surface acoustic wave filter according to embodiment 4 of the invention.

Fig. 6 is a measurement circuit diagram according to embodiment 4 of the invention.

Fig. 7 is a structural view showing the surface acoustic wave filter according to embodiment 5 of th invention.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will be explained her inafter.

Embodiment 1

Embodiment 1 of the invention is shown. As a piezoelectric substrate, a 64° Y cut transmission lithium niobate substrate is used to constitute a filter. A structure of electrodes is shown in Fig. 1.

Reference numeral 101 denotes an interdigital transducer for input comprising a pair of 1) first comb-like electrodes each positioned at one wavelength interval in a parallel manner and provided with an input terminal 104 and 2) second comb-like electrodes each positioned at one wavelength interval in a parallel manner and provided with a grounding terminal, each of said first electrodes being interposed at a half wavelength between corresponding second electrodes. Reference numerals 102-1 and 102-2 denote interdigital transducer for output comprising a pair of first comb-like electrodes each positioned at one wavelength interval in a parallel manner and provided with a grounding terminal and second comb-like electrodes each positioned at one wavelength interval in a parallel manner and provided with an output terminal 105 and 106, each of said first electrodes being interposed at a half wavelength between corresponding second electrodes. Reference numerals 103-1 and 103-2 denote reflectors. However, for simplification, the interdigital transducer electrodes and the reflectors are described in decreased numbers in the drawings. The property of such filter was measured. As a result of measurement, a signal smaller by 3dB than in the case of the conventional filter can be obtained at the output terminals 105 and 106. In a mobile communication field, the SAW filter may be used for a filter for output of a local oscillator in order to filter a signal from the local oscillator and distribute the signal into a transmitter circuit and a receiver circuit.

Embodiment 2

Next, embodiment 2 of the invention is shown. As a piezoelectric substrate, a 64° Y cut transmission lithium niobate substrate is used to constitute a filter. A structure of an electrode shown in Fig. 2 is the same structure as in Fig. 1 except the number of comb-like electrodes. Reference numeral 201 denotes a central interdigital transducer electrode for input, reference numerals 202-1 and 202-2 denote side interdigital transducers for output. Reference numerals 203-1 and 203-2 denote reflectors, and reference numerals 205 and 206 denote output terminals. However, for simplification, the interdigital transducer electrodes and the reflectors are described in decreased numbers in the drawings. Furthermore, th number of pairs of the comb-like electrodes in the central interdigital transducer 201 is set to approximately the same as that of

each of the side interdigital transducers 202-1 and 202-2, so that the input impedance and the output impedance becomes approximately equal to each other, namely, to 50 ohms in this mbodiment. Then, the property of such filter was measured. As a result of measurement, a signal smaller than 3dB than in the case of the conventional filter can be obtained at output terminals 205 and 206, and the input impedance and the output impedance can be all set to 50 ohms.

Embodiment 3

Next, embodiment 3 of the invention is shown. As a piezoelectric substrate, a 64° Y cut transmission lithium niobate substrate is used to constitute a filter. A structure of an electrode shown in Fig. 3 is the same as in Fig. 1 except spaces between the central and the side transducers. Reference numeral 301 denotes the central interdigital transducer for input. Reference numerals 302-1 and 302-2 denote the side interdigital transducers for output. Reference numerals 303-1 and 303-2 denote reflectors, reference numeral 304 denotes an input terminal, and reference numerals 305-1 and 305-2 denote output terminals. However, for simplification, the interdigital transducer electrodes and the reflectors are described in decreased numbers in the drawings. The filter according to embodiment 3 is constituted in such a manner that spaces ΔS1 and ΔS2 at the right side and the left side between the innermost electrode of each of the interdigital transducer electrodes 302-1 and 302-2 and the outermost electrode of the central interdigital transducer 301 differ from each other by one half wavelength of surface acoustic wave generated on the piezoelectric . The side interdigital transducers 302-1 and 302-2 at both ends comprises first comb-like electrodes provided with a grounding terminal respectively and connected to a ground line and also second comb-like electrodes provided with a output terminals 305-1 and 305-2 used as a signal line, whereby a signal is applied between signal lines 305-1 and 305-2 of the side interdigital transducer electrodes at both ends. As a consequence, each signal output from the side interdigital transducer electrodes has an equal size and a phase different by 180° to each other. In other words, in such a structure, it is possible to form a structure in which the input signal is an unbalanced signal and the output signals are balanced signals.

The property of this filter was measured by connecting a balun 401 which can convert signals between a 50 ohm unbalanced signal and a 200 ohm balanced signal as shown in Fig. 4, through which the balanced signal form the output 305-1 and 305-2 are converted into unbalanced signals. As a result of measurement, approximately the same property can be obtained as in the case of the conventional unbalanced signal. Besides, it was confirmed that the phase difference between output terminals can be set to 180°. By finely adjusting the space difference (ΔS1 - ΔS2), it is possibl to control a phase shift between the balanced output terminals 305-1 and 305-2 if the output signal would shift by some degrees from the predetermined phase.

Embodiment 4

Next, embodiment 4 of the present invention is shown in Fig. 4. As a piezoelectric substrate, a 64° Y cut transmission lithium niobate substrate is used to constitute a filter. A structure of electrodes shown in Fig. 5 is the same as in Fig. 2 except that two grounding terminals are connected to each other and an output terminal and a connecting terminal of one of the side interdigital transducers is converted into each other in order to get the same space difference effect as in Fig. 3 while keeping the same space between the central transducer for input and the side transducer for output.

Reference numeral 501 denotes a central interdigital transducer for input. Reference numeral 502-1 and 502-2 denote side interdigital transducers for output. Reference numerals 503-1 and 503-2 denote reflectors. Reference numeral 504 denote an input terminal. Reference numerals 505-1 and 505-2 denote output terminals while the other terminals are connected to each other. However, for simplification, the interdigital transducer electrodes and the reflectors are described in decreased numbers in the drawings. The filter is constituted in such a manner that a space ΔS3 between the innermost electrode of the side interdigital transducer 502-2 and the outermost electrode of the central interdigital transducer 501 are equal to a space ΔS4 between the innermost electrode of the side interdigital transducer 502-1 and the outermost electrode of the central interdigital transducer 501. As a consequence, both signal output from the side interdigital transducer electrodes have an equal size and a phase different by 180° to each other. In other words, in such a structure, it is possible to form a structure in which the input signal is an unbalanced signal and the output signals are balanced signals.

In a case of 50 ohms of input impedance, 200, 100 or 50 ohms of output impedance can be obtained depending on a ratio of the central interdigital transducer to the side interdigital transducer with respect of the number of electrode pairs.

Embodiment 5

Next, embodiment 5 of the invention is shown. As a piezoelectric substrate, a 64° Y cut transmission lithium niobate substrate is used to constitute a filter. A structure of electrodes shown in Fig. 7 is substantially the same as that in Fig. 3 except the grounding terminals are connected each other. Reference numeral 701 denotes a central interdigital transducer electrode for input. Reference numerals 702-1 and 702-2 denote side interdigital transducers for output. Reference numerals 703-1 and 703-2 denote reflectors, reference numeral 704 denotes an input terminal, and reference num rals 705-1 and 705-2 denote output terminals. However, for

simplification, the interdigital transducer electrodes and the reflectors are described in decreased numbers in the drawings. The filter according to embodiment 5 is constituted by having th same spaces Δ S1 and Δ S2 as in Fig. 3, so that there was obtained the same effect as in Fig. 3 (the embodiment 3).

Furthermore, as a piezoelectric body for forming a surface acoustic wave resonators, a 64° Y cut transmission lithium niobate substrate was used, but it goes without saying that a similar advantage can be provided by using, for example, the similar piezoelectric body, for example, a lithium tantalate, a crystal substrate or the like.

In a modification of the embodiments 4 and 5, the connecting terminals may be grounded and there is obtained the same effect as the connection with each other.

In another embodiment, in spite of the interdigital transducer comprising one central interdigital transducer for input and tow side interdigital transducer for output, the interdigital transducer may comprises two interdigital transducer for input and three interdigital transducers, one for input interposed between the first and the second transducers for output and the other for input interposed between the second and the third transducers for output.

Claims

1. A surface acoustic wave filter comprising:

   a piezoelectric substrate, surface wave reflectors formed with an interval therebetween on said piezoelectric substrate, and interdigital transducers interposed between said surface wave reflectors on said piezoelectric substrate, wherein said interdigital transducers comprises a central interdigital transducer for input, at least two side interdigital transducers, at least one located at one of opposite sides of said central interdigital transducer and the other one located at the other one of opposite sides of said central interdigital transducer,
   said central interdigital transducer for input comprising a pair of first comb-like electrodes provided with an input terminal and second comb-like electrodes provided with a grounding terminal;
   each of said interdigital transducers for output comprising a pair of first comb-like electrodes provided with a connecting terminal and second comb-like electrodes provided with an output terminal, said connecting terminals being connected to each other or grounded together so as to distribute one signal entering into said central interdigital transducer into at least two signals each outputted from each output t rminal of said side interdigital transducers.

2. The surface acoustic wave filter according to claim 1, wherein the number of electrodes of said central interdigital transducer for input is substantially equal to that of each said side interdigital transducer for output.

3. A balanced-unbalanced type surface acoustic wave filter according to claim 1, wherein a space between said second comb-like electrodes provided with an outputting terminal of said first side interdigital transducer and said first comb-like electrodes provided with an inputting terminal of said central interdigital transducer is different at one or odd number times of half wavelength (λ/2) from a space between said second comb-like electrodes provided with an outputting terminal of said second side interdigital transducer and said first comb-like electrodes provided with an inputting terminal of said central interdigital transducer, whereby one unbalanced input signal entering into said central interdigital transducer is distributed into at least two output signals having balanced relation to each other with respect to phase.

4. The balanced-unbalanced type surface acoustic wave filter according to claim 3, wherein the number of electrodes of each said side interdigital transducer for output is smaller than that of said central interdigital transducer for input so as to get a larger impedance of said side interdigital transducer.

5. The balanced-unbalanced type surface acoustic wave filter according to claim 3, wherein the space between an innermost electrode of said first side interdigital transducer and one outermost electrode of said central interdigital transducer being different at one or odd number times of half wavelength (λ/2) from the space between an innermost electrode of said second side interdigital transducer and an other outermost electrode of said central interdigital transducer.

6. The balanced-unbalanced type surface acoustic wave filter according to claim 3, wherein the space between an innermost electrode of said first side interdigital transducer and one outermost electrode of said central interdigital transducer being substantially the same as the space between an innermost electrode of said second side interdigital transducer and an other outermost electrode of said central interdigital transducer.

Fig. 1

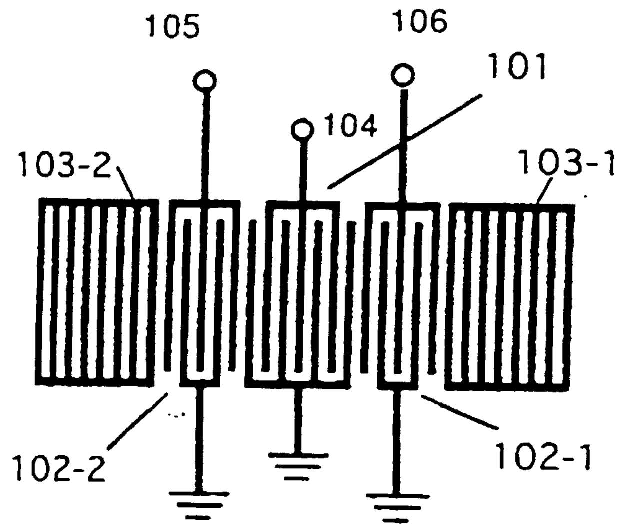

105
106
101
104
103-2
103-1
102-2
102-1

Fig. 2

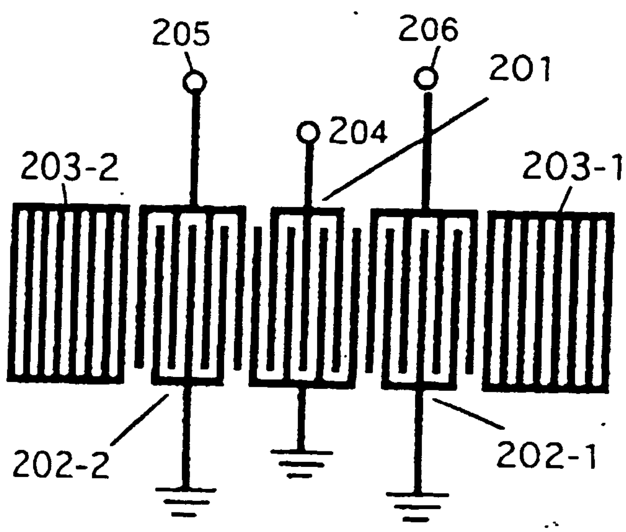

205
206
201
204
203-2
203-1
202-2
202-1

Fig. 3

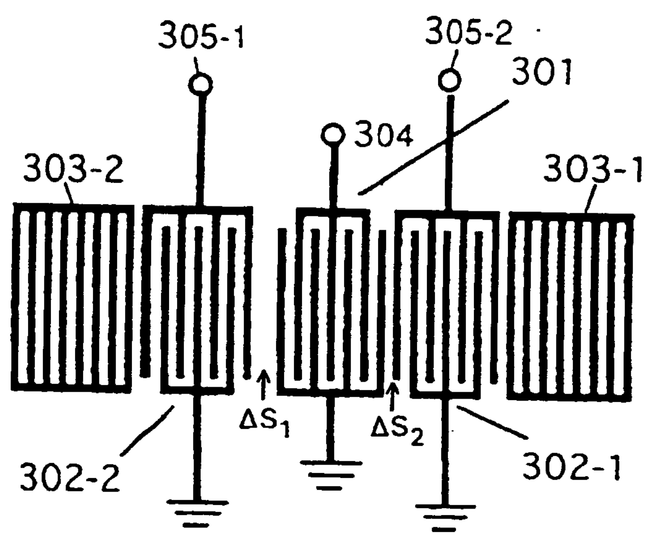


Fig. 4

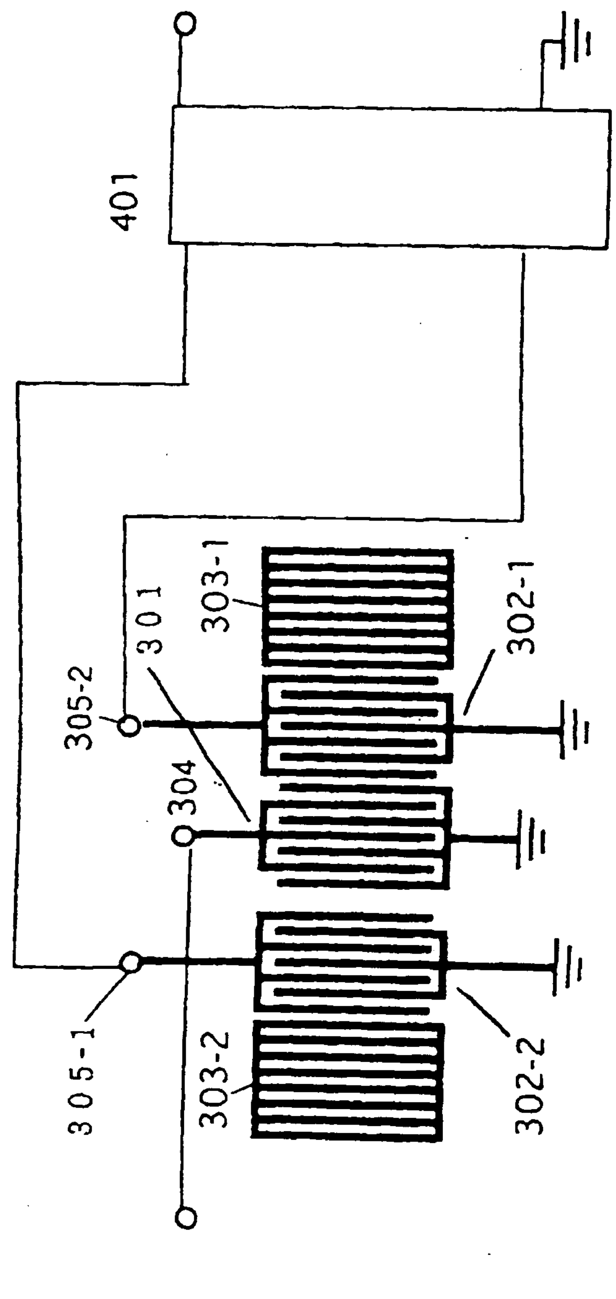
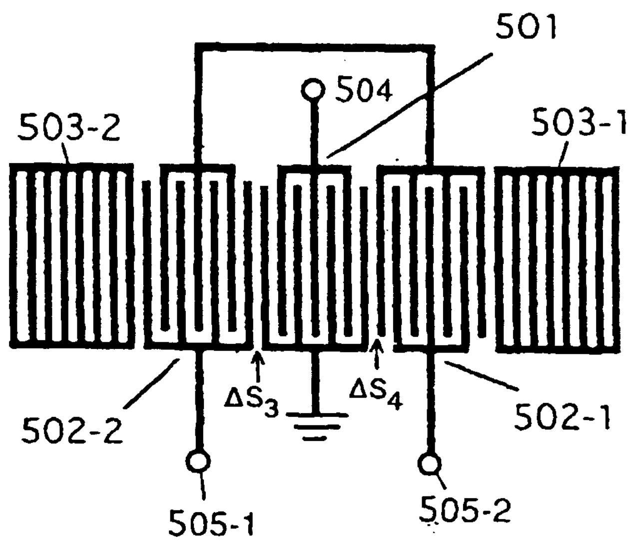


Fig. 5



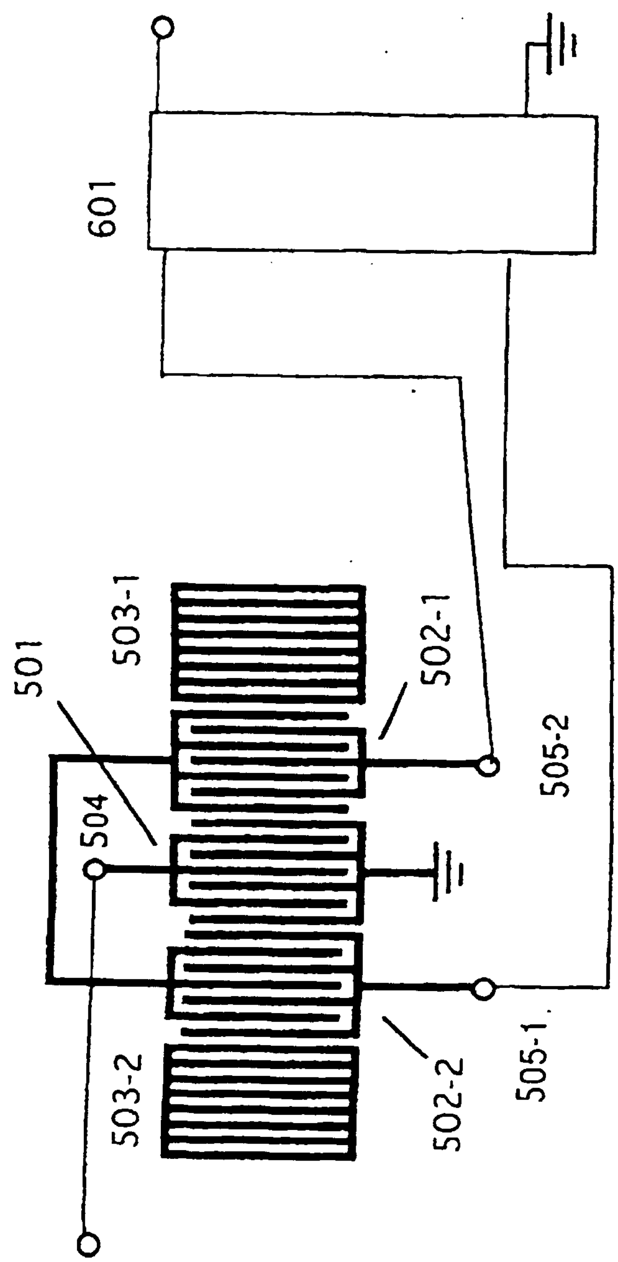


Fig. 6

Fig. 7